

Patent Application

of

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for

**Test Pin Back Surface in Probe Apparatus for Low Wear
Multiple Contacting with Conductive Elastomer**

FIELD OF INVENTION

The present invention relates to contact interfaces of electrical contact pins with conductive elastomer. More particular, the present invention relates to electrical test pin back end shaped for low wear multiple contacting with conductive elastomer in a probe apparatus.

BACKGROUND OF INVENTION

An anisotropic conductive elastomer (ACE) is a favorable structure for applications where a large number of independent electrically conductive and mechanically resilient paths need to be two dimensionally arrayed for contacting tightly arrayed contacts. As the

miniaturization of circuit chips advances, ACEs are increasingly utilized in between the circuit chip and peripheral devices. In the field of circuit chip testing, ACEs are attractive structural elements that may assist in reducing a probe apparatus' complexity.

Commercially available ACEs may be configured with a number of substantially evenly and parallel arrayed metal filaments extending between two opposite access planes. The traces are resiliently held in position by an elastic material such as silicon rubber. The ACE may establish conductive connection between oppositely facing contacts of mirrored contact arrays.

The use of ACEs in a chip test apparatus poses particular challenges related to the high numbers of temporary contacting that have to be performed with minimum degradation of path resistance and structural wear of the ACE. In well known applications in which the ACE is directly contacted with the test contacts, the repeated contacting causes debris to form on the ACE surface. Due to the substantially closed surface configuration of the ACE, the debris is depositing in the direct vicinity of the filament ends and may compromise the contact quality in the interface at a relatively early stage compared to other well known probe designs. Cleansing the ACE from debris is unfortunately problematic since it requires the use of chemicals that may alter the ACE's physical properties or otherwise harm the filler material. In addition, the chemicals may be difficult to remove from an eventually sponge like ACE configuration. Therefore, there exists a need for a probe apparatus capable of utilizing an ACE.

without risk of debris at the ACE surfaces and without need for cleansing the ACE. The present invention addresses this need.

Another challenge in the use of ACE for multiple contacting is mechanical wear of the ACE structure. Particularly in the vicinity of repetitively impinging rigid contacting structures, the ACE may suffer increased wear due to excessive local deformation and/or stress of the filament as well as the elastic filler material. Therefore, there exists a need for an ACE multiplicatively indenting structures and a probe apparatus configured for minimizing wear of the ACE. The present invention addresses also this need.

SUMMARY OF INVENTION

A probe apparatus for preferably testing packaged circuit chips combines an ACE with plunger pins placed in between the ACE and the test contact. A plunger pin provides a front end for contacting the chips' test contacts and a back end configured for impinging the ACE. The contact end may be configured in conjunction with the test contacts particularities whereas the plunger pins' back ends are specifically configured for minimizing ACE wear and contact resistance degradation. The plunger pins are arrayed and slide ably held in a carrier frame that may be readily removed for cleansing. The plunger pins have guiding portions that correspond to guide perforations in the carrier frame. The plunger pins feature also a central recess that corresponds to a snap feature in the frame to

prevent the plunger pins from falling out during the cleansing operation.

The back surfaces have a curvature such that for a given indentation depth of the back surface into the ACE, the ACE's relevant deformation in the indentation vicinity remains on an overall minimum. Relevant deformation in the indentation vicinity may include but is not limited to surface shear between the back surface and ACE, tensile surface stress of the ACE surface, angular ACE surface displacement and deformation gradient in the ACE's indenting vicinity.

BRIEF DESCRIPTION OF THE FIGURES

Fig. 1 is a front view of an assembled simplified exemplary probe apparatus while testing an exemplary packaged circuit chip.

Fig. 2 is a frontal exploded view of the probe apparatus of **Fig. 1**.

Fig. 3 is a perspective exploded view of the probe apparatus of **Fig. 1**.

Fig. 4 is a section view of the probe apparatus of **Fig. 1**.

Fig. 5 is a view of a detail encircled and labeled "A" in **Fig. 4**.

Fig. 6 shows a first exemplary plunger pin.

Fig. 7 depicts a second exemplary plunger pin.

Fig. 8 is an exemplary experimentally determined graph illustrating the relation of indentation opposing force and indentation depth of the first exemplary plunger pin experimentally fabricated and tested in combination with a commercially available anisotropic conductive elastomer (ACE).

DETAILED DESCRIPTION

In the following the terms "horizontal, vertical, upwards, downwards, bottom, top, above, below" are used in conjunction with the Figures. As it may be clear to anyone skilled in the art, these terms are used solely for the purpose of ease of understanding and to describe spatial relations of elements with respect to each other.

As in **Fig. 1**, a probe apparatus **10** may be configured for multiple testing of electronic circuitry **7**, which is preferably in a well known packaged condition with device terminals **9** being accessible on a surface of the package **8**. The probe apparatus **10** features plunger pins **20**, each having a center axis **21** that is substantially parallel to an impinging direction of plunger pins **20** onto the device terminals **9**.

The plunger pins **20** are embedded in a carrier frame **30** and moveable along their respective center axes **21**. The

carrier frame 30 in turn is attached to an apparatus housing 60 with frame fixtures 61, which provide precise positioning of the carrier frame 30 and consequently the plunger pins 20. The frame fixtures 61 may be optionally configured to be readily removed from and reattached at the carrier frame 30 as may be well appreciated by anyone skilled in the art. In that fashion, the plunger pins 20 may be easily handled for cleansing operations during which debris may be removed from the plunger pins 20. Debris may form on and/or in the vicinity of the plunger pins 20 during eventual repetitive scribing of the plunger pins 20 on the device terminals 9 as is well known in the art.

The apparatus housing 60 further holds a contact terminal 50 in the preferred configuration of a well known printed circuit board (PCB). Sandwiched between the PCB 50 and the plunger pins 20 is an anisotropic conductive elastomer (ACE) 40 well known in the art for providing insulated conductive paths within an elastic structure. The present invention includes embodiments in which the contact terminal 50 may be any well known separate or integral structure of the probe apparatus 10 that provide base contacts 55 (see **Figs. 2-4**) in a useful fashion as described in the below.

In **Figs. 2, 3**, the probe apparatus 10 is illustrated in exploded view. The plunger pins 20 in a first basic configuration feature back surfaces 22 and front ends 23 with a number of crown peaks 231 substantially rotationally symmetric arrayed with respect to their center axes 21. Particularly in combination with device terminals 9 configured as well known ball grid array, the concentric

crown peaks **231** provide for a self centering effect that prevents undesirable lateral forces resulting from an eventual slight out of center contacting of the pin front ends **23** with ball grid terminals **9**. The present invention includes embodiments in which the front end **23** has any other well known configuration suitable for low resistive contacting of varied shaped device terminals **9**.

The plunger pins **20** are preferably configured to be slide ably guided in a limited fashion along their respective center axes **21**. For that purpose, the plunger pins **20** feature guide sections **24, 26** extending along their respective center axes **21**. The guide sections **24, 26** correspond to guiding perforations **35** that extend between the frame top **31** and the frame bottom **32**. The plunger pins **20** further feature recess sections **25** that correspond to retention flanges **36** inside the guiding perforations **35**.

The carrier frame **30** is preferably a planar structure having a frame top **31** and a frame bottom **32** where the guiding perforation **35** may be fabricated from one or both sides such that the retention flange **36** is either in the middle of the guiding perforation **35** or at one of frame top **31** and frame bottom **32**. The carrier frame **30** further features fixture fits **37** that correspond to the frame fixtures **61** as may be well appreciated by anyone skilled in the art.

The ACE **40** provides on one hand an insulated opposing force via the pin back surfaces **22** and the pin front ends **23** onto the device terminals **9** as result of a relative motion of the probe apparatus **10** towards the test chip **7** along the

impinging direction. The relative motion eventually results in a penetration depth by which the pin front ends **23** scribe and sink into their opposing device terminals **9** and an indentation depth **PD** (see **Fig. 5**) by which the pin back surfaces **22** are forced into the resiliently deflecting ACE bottom **42** where it produces a temporary indentation **45**.

Simultaneously to providing the impinging opposing force, the ACE **40** contributes to establishing insulated conductive paths between the pin front ends **23** and the base contacts **55**. As the pin back surfaces **22** temporarily indent the ACE bottom **42** during one of many chip **7** testing cycles, the ACE **40** is held in position via the PCB bottom **52** pressing against the ACE top **41**. The PCB base contacts **55** indent thereby the ACE top **21**. Due to the indentation on both sides of the ACE **40** low resistive and insulated conductive connections are established between respective pin back surfaces **23** and base contacts **55** via conductive filaments arrayed and parallel extending between the ACE top **41** and ACE bottom **42** as is well known in the art.

Positions of base contacts **55** with respect to the center axes **21** are defined in correspondence with the spatial orientation of the conductive filament extending between the ACE top **41** and the ACE bottom **42**. For example, an ACE **40** may be fabricated with perpendicular extending conductive filament in which case the base contacts **55** may be aligned and centered with their respective plunger pins' **20** center axes **21**. In another example where an ACE **40** may be fabricated with angular extending conductive filaments, the base contacts **55** may be in an offset to their

respective plunger pins' **20** center axes **21** that corresponds to the offset of the angular filaments' ends.

ACE **40** with angular filaments may be preferably utilized due to its eventual improved filament deflection within the ACE structure resulting from a pin indentation. An exemplary ACE **40** may have gold plated metal filaments with a pitch of about 0.1mm and an offset of the opposing filament ends of about 0.5 mm for an ACE height **43** of about 1 mm.

PCB **50** and ACE **40** are substantially fixedly held within receptacle features **62, 63** such that the contact between base contacts **55** and ACE top is preferably substantially permanent. In addition, the base contacts **55** may eventually extend only slightly below the PCB bottom **52** such that the ACE top **41** may support itself additionally directly against the PCB bottom **52** during indentation of the pin back surfaces **22**. Thus, substantial repetitive dynamic deformation is mainly observable in the vicinity of the pin indentations **45** and eventual transition curvatures **46**.

In the cross section view of **Fig. 4** the retention flange **36** is shown with a height **361**. The limits along which the plunger pins **20** are slide able are defined by the finite length of the recess section **25** minus the height **361** of the retention flange. During assembly insertion of the plunger pins **20** into the guiding perforation **35**, the retention flange is non destructively and resiliently deformed. This is accomplished by having the carrier frame of a sufficiently elastic material composition selected in

combination with the offset **O1** between retention flange **36** and guide circumference **GD**. In an exemplary embodiment, the guide circumference **GD** may be a circular diameter of about 0.4mm.

Fig. 5 is an enlarged detailed view of the pin indenting vicinity in an ACE **40** where relevant deformations take place. Relevant deformations may include but are not limited to surface shear along the contact boundary **47** between the back surface and ACE, tensile surface stress of the ACE bottom **42**, angular ACE surface displacement and deformation gradient in the ACE **40** structure in the vicinity of pin indentations **45** and transition curvatures **46**. Dependent on the ACE's **40** deformation behavior the transition curvature **46** may vary. In cases where the ACE **40** has a substantially integer surface layer with a tensile strength and/or stiffness larger than the ACE's **40** core structure, the transition curvature **46** may increase correspondingly and as may be well appreciated by anyone skilled in the art.

Referring also to **Fig. 6**, relevant deformations are brought in one aspect to a minimum by providing the back surface **22** with a curvature that is rotationally symmetric with respect to the center axis **21** and that is continuous at least within the pin indentation area **45**. The back surface **22** has a center radius **RC** that is at a maximum in proximity of the center axis **21** and decreases towards a back circumference **BD** where it transforms into peripheral radius **RP**. In a simplified embodiment, the curvature center radius **RC** is infinite. The back surface **22** may be also defined by the center radius **RC** and the peripheral radius

RP alone. The height **BH** of the back surface **22** may be defined at least equal with the indentation depth **PD**. The continuous curvature of the back surface **23** minimized the deformation gradient in the structural body of the ACE **40** immediately adjacent the indentation area **45**. The deformation gradient is the rate at which deformation changes within a structure.

Another aspect in minimizing relevant deformations is selecting the curvature of the back surface **22** such that bending stress and eventual sheer stress between the ACE's **40** bottom surface and the back surface **22** is substantially eliminated along the contact boundary **47**. This is accomplished in the present invention by defining the back surface **22** additionally such that it is substantially tangential with the ACE's **40** bottom surface along the contact boundary **47** at least at a maximum indentation depth **PD** where ACE's **40** strain in the indentation vicinity is at a maximum. This means that along the contact boundary **47**, the back surface **22** and the ACE's **40** bottom surface share a common tangent angle **MA**.

As may be well appreciated by anyone skilled in the art, the deformation gradient may be at a minimum in the indentation vicinity of the ACE **40** structure where the smallest surface curvature of the indentation area **45** and eventual transition curvature **46** are kept to a maximum. This would mean for the sole purpose of minimizing deformation gradient in the ACE **40** structure, indentation area **45** curvature and transition curvature **46** would be equally brought to a maximum by maximizing surface strength and surface stiffness of the ACE bottom **42** surface.

Unfortunately this would also increase the overall deformation circumference **DD**. In a practical case of tightly spaced device terminals **9**, the deformation circumference **DD** may not be larger than a minimum pitch of the device terminals **9** to secure insulated opposing forces onto each plunger pin **20** as may be well appreciated by anyone skilled in the art.

The present invention best balances the need to keep the overall circumference **DD** below maximum device terminal **9** pitch while keeping the deformation gradient to a minimum by defining the back surface **22** at one hand with continuous curvature that is at a maximum at the center axis **21** and decreases in direction away from the center axis **21** and on the other hand such that the back surface **22** shares a common tangent angle **MA** with the ACE's **40** bottom surface at least along the contact boundary **47**. In that way, surface shear between the back surface **22** and ACE **40** as well as tensile surface stress of the ACE bottom **42** surface are also kept to a feasible minimum.

Another concern in shaping the back surface **22** is the interaction of the back surface **22** with metal filaments that also deflect during indentation. To minimize the risk of plastic lateral deformation of the filaments due to excessive lateral filament deviation within the ACE **40**, the overall angular displacement in the indentation area **45** is preferably kept to a minimum. The embodiments of the present invention comply with this identified requirement.

In another embodiment, the back surface **22** may have a curvature defined such that tangency with the ACE's **40**

bottom surface is substantially maintained during the indentation process where the contact boundary **47** gradually increases between zero diameter at indentation begin up to maximum contact boundary **47** diameter at maximum indentation depth **PD**. An ellipsoidal back surface **22** may comply with this identified requirement. The ellipsoidal back surface **22** may have a cross section in which the short axis of the ellipse contour substantially coincides with the center axis **21**.

In a further embodiment, the back surface **22** may have a curvature defined such that the contact boundary **47** gradually increased/decreases between zero diameter at indentation begin/end up to maximum contact boundary **47** diameter at maximum indentation depth **PD**. The ellipsoidal back surface **22** may comply with this identified requirement. In that fashion, the relation of opposing force and indentation depth may be adjusted as exemplarily depicted in **Fig. 8** where the horizontal axis shows indentation depth in mm and the vertical axis shows opposing force in kp. The graph of **Fig. 8** was experimentally obtained from a plunger pin having a back circumference **BD** of about 0.4mm, an infinite center radius **RC** directly transforming into a peripheral radius of about 0.15mm. The center radius **RC** has a radial extension of about 0.05mm off the center axis **21**. Preferred indentation depth **PD** is about 0.15 mm resulting in an opposing force of about 20g for an ACE **40**.

The ellipsoidal back surface **22** is relatively simple defined for fabrication purposes and providing continuously outward decreasing curvature radius that provides during

indentation progress for common tangent angle **MA**, continuously increasing contact boundary **47**, minimal overall angular ACE **40** surface deflection and feasible deflection gradient.

In further embodiment, the back surface **22** may seamlessly transition into the back circumference **BD** avoiding excess pressure on the contact boundary **47** in cases where the indentation depth **PD** exceeds the back surface height **BH**.

The exemplary plunger pin **20** of **Fig. 6** has two guide sections **24**, **26** immediately adjacent the back surface **22** and the front end **23**. The recess section **25** is placed in between. Front circumference **TD** and back circumference **BD** are the same time guide circumference **GD**. In this embodiment, the contact boundary **47** may be slightly less than the back and front circumferences **BD**, **TD**.

The opposing force maximum may be adjusted by independently scaling the back surface **22** such that the back circumference **BD** is independent from the guide circumference **GD**. Especially with increasingly large numbers of plunger pins **20** arrayed within the probe apparatus **10** for simultaneous contacting, the opposing force may be reduced to keep the overall forces in the probe apparatus **10** within feasible ranges as may be well appreciated by anyone skilled in the art. **Fig. 7** depicts an exemplary plunger pin **20** having a reduced back circumference **BD**. In addition, the plunger pin **20** of **Fig. 7** utilizes only a single guide section **24** with the recess section **25** being placed immediately adjacent the front end **23**. The recess section **25** may be thereby utilized as

guiding section as well. A corresponding retention flange **36** may be placed at the frame bottom **32**. The offset between the front end **23** and the recess circumference **RD** may assist in preventing scribing debris to enter the guiding perforation **35**.

The present invention includes embodiments in which the retention flange **36** may be fabricated of a separate material layer specifically configured for elasticity and sealing.

Accordingly, the scope of the invention described in the specification above is set forth by the following claims and their legal equivalence: